

# 1 COVER SHEET – ROUND II - TECHNICAL APPLICATION

**Funding Opportunity No:** DTFH61-08-RA-00010  
**Date:** 3 December 2008  
**Title:** Fully Precast Bridge Bents for Use in Seismic Regions  
**Primary Contact:** Dr. Lee Marsh  
BERGER/ABAM Engineers Inc.  
33301 Ninth Avenue South  
Federal Way, WA 98003  
Tel: (206)-431-2300, Fax (206)-431-2250  
email: [Lee.Marsh@abam.com](mailto:Lee.Marsh@abam.com)  
**Business type:** Consulting Engineers  
**Funding requested:** \$399,949 (FHWA), \$154,449 cost sharing

## Summary of Innovation:

The product innovation consists of a totally precast concrete bridge bent system that can be used in seismic regions. The proposed system uses a small number of large bars grouted in ducts to achieve the connection between components so that it can be constructed rapidly and safely, and in contrast with systems developed previously, it has the structural resilience to resist earthquake shaking. To apply the system in a wide range of girder bridges, the product innovation will be accompanied by a design methodology, as well as guidelines for fabricators, contractors, and practicing bridge engineers. The proposal team membership includes experienced practitioners of all the disciplines needed to finalize the system and implement it in the field. Specifically, the team includes bridge design engineers, a general contractor, a precast producer, a university structural test lab, and the Washington State Department of Transportation (WSDOT). Most of the components have already been demonstrated either in the field or in the laboratory. The final product development, to be conducted under the sponsorship of FHWA, will include (1) proof testing of modifications of the product that will increase its versatility, (2) development of guidelines and specifications (3) development of design examples, and (4) pilot deployment of the system.

## 2 Detailed Project Management Plan

**2.1 Innovation Description and Highways for Life (HfL) Goals.** This proposal describes a product innovation related to Accelerated Bridge Construction (ABC) in seismic regions. The innovation consists of a totally precast bridge bent system, including precast columns and beams. To accelerate construction without sacrificing seismic resistance, the beam-to-column connections are made with a small number of large-diameter reinforcing bars (e.g., # 18s) that are grouted into much larger-diameter ducts (e.g., 8-in. diameter).

The intermediate transverse frames that support the bridge superstructure are referred to as ‘bents’. They support the longitudinal girders and are typically constructed from cast-in-place reinforced concrete. Cast-in-place construction is widely used, because state DOTs have developed standard plans to based on it, the national design specifications directly address it, and contractors have built up expertise with it. However, the process of casting these concrete elements in place, especially high above the ground, exposes workers to potential injury and accidents, is time consuming, and is expensive. In addition, the time required to cast on site requires lengthy lane closures or restrictions, which delays traffic and causes hazards to both workers and the travelling public.

Prefabrication of modular components offers an attractive alternative. This concept has been used for many years for bridge girders, which are often prefabricated in steel or prestressed concrete and are lifted into place once the bents have been constructed. Prefabricated bridge bent systems have been developed by a few non-seismic states, such as Texas, while states with active seismicity have rarely used precast elements in bridges for anything but the longitudinal girders.

Contractors like to use straight components, because they are easy to transport. This choice leads designers to locate the connections at intersections between members, but unfortunately these locations are precisely the places where strength and ductility are most needed to resist seismic loading. In addition, the features of a connection that make it easy to erect (e.g., limited connectivity) in most cases lead to inferior seismic performance (e.g., low strength). To extend the use of precasting to bents in seismically active regions, it is necessary to develop a system that both can be constructed rapidly and has good seismic resistance.

Our product makes it possible to build economically, rapidly and safely in seismic regions. The innovation meets all four of the HfL goals, as listed below.

***Safety Improvements.*** Use of prefabrication reduces time spent on site and the need to schedule construction activities during the night. Night work is especially dangerous because more traffic accidents occur at night, visibility is worse, and workers are less attentive. Furthermore, reinforced concrete structures are particularly vulnerable during construction, when their safety depends on the integrity of the formwork and shoring, which are less stringently designed than is the finished structure. Precasting avoids the need for such formwork and shoring.

***Reducing congestion due to construction.*** Reduced time on site reduces the time during which lanes must be closed or restricted, or traffic speed limited. In some cases a component may be erected in such a short time that a “rolling slowdown,” rather than a complete lane or roadway closure, is feasible. This option has the huge benefit of eliminating the need to stop traffic.

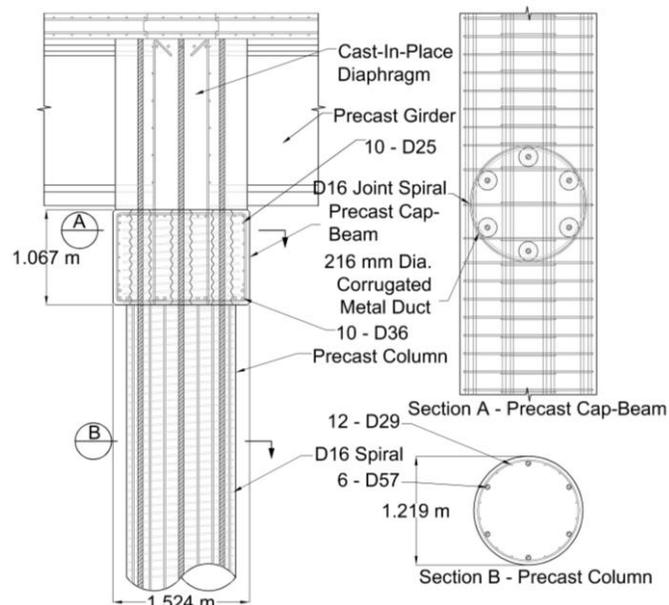
***Accelerating construction.*** Prefabrication can reduce total contract time. However, even more importantly, it reduces the time spent on site, which determines the extent of the interruption to traffic, the fuel wasted by delays, and the public’s support for the agency sponsoring the

construction. Prefabrication is also plays a major role in total project cost. The fact that several successful precasting jobs have been the result of voluntary changes through Value Engineering or Cost Reduction Incentive Proposals (CRIPs) is an indication of the potential for cost savings.

**Improving quality.** Precast units are often constructed in specialized plants, where repetitive construction permits use of high-quality steel forms, giving rise to accurate dimensional control. Plant operations also allow tight quality control of material properties, the possibility of prestressing (to inhibit cracking), rapid production (through hot curing of the concrete), and good schedule control (weather independent). Some of these advantages are also available with site precasting, which allows workers to work at ground level and eliminates the need for, and limitations of, long-distance transportation to the site.

**2.2 Market Need and Potential Payoff for Routine Practice.** The market for Accelerated Bridge Construction products is beyond question and is already a priority for FHWA. More than 150,000 bridges – 25 percent of bridges in the National Bridge Inventory – are classified as functionally or structurally obsolete (FHWA, 2008), and will require replacement or retrofit in the coming years. The Texas Transportation Institute estimates that \$78 billion annually are wasted in delays and unnecessary fuel consumption, much of which occurs because of construction activities. Additional benefits would result from lower construction costs through shorter construction times, especially by virtue of fewer lane restrictions, channelization changes, and time under mobilization.

If the benefits are so clear, it is reasonable to ask why prefabrication has not been pursued more aggressively before. Discussions with contractors suggest that the primary reasons lie with a reluctance to embrace new methodologies until their performance has been proven and design specifications and guidelines are available. That reluctance is particularly understandable in seismic regions, because, until recently, methods of making connections that are both structurally robust and quick to assemble were scarce, relatively unknown, and not addressed in design specifications. Fortunately, recent and ongoing research with precast concrete building and bridge systems (Stanton and Nakaki, 2002, Pang et al. 2008-1) have spawned new concepts that have been developed into the promising system proposed herein.



**Figure 1. Typical Implementation of Product Concept**

To deploy this product in a wide range of applications, it is necessary to develop general design tools for bridge engineers and, eventually, proposals suitable for adoption in the AASHTO Load and Resistance Factor Design (LRFD) Specifications.

**2.3 Differences from Other Practices.** The primary difference between the proposed product and conventional cast-in-place bridge bent construction is the prefabrication of components and their subsequent connection in their final positions. The critical outcome is the reduction in time spent on site because formwork and reinforcing steel do not need to be built on site, and the concrete does not need to gain strength on site prior to erection of the next component. For example, building a cast-in-place cap beam can take about two months, whereas a precast cap beam can be set and grouted in place in two days.

**2.4 Previously Completed Product Development.** Most of the product development for the proposed large-bar, large-duct precast system builds has been sponsored by WSDOT, with the active input of numerous contractors and fabricators. A typical configuration is shown in Fig. 1.

During the initial product development, three main issues were addressed: (1) constructability of the system, (2) anchorage of the large bars within the space available, and (3) seismic response of the precast column-to-cap beam connection.

***Constructability.*** The connection between the column and cap beam is made with large bars that project from the top of the column and are grouted into ducts in the cap beam. The advantage of using a small number of large bars (as opposed to numerous small bars) is the reduction in the number of alignments needed. The proposed system uses #18 (2.25-in dia.) bars in 8-in. diameter ducts to maximize assembly tolerances. Contractors have indicated that these systems would be easy and economical to construct (Stanton et al. 2006).

***Development of Large Bars.*** Initially, team members were concerned that the long anchorage lengths required by current codes for large bars would exceed the space available in typical cap beams. Development of these bars is particularly demanding under the cyclic loads caused by earthquakes. To address this concern, 14 pullout tests were performed with bars as large as #18. The tests and accompanying nonlinear finite element analyses showed that large bars confined by ducts and typical cap beam reinforcement can develop their yield and fracture stresses in as little as six and ten bar diameters, respectively (Steuck et al. 2008). The typical depth of cap beams (e.g., 42 in.) provides ample space to develop these large bars.

***Seismic Performance of Solid Column Connection.*** Another concern was that the large-bar system might not have the same seismic performance as a typical cast-in-place reinforced concrete system. To address this concern, cyclic tests were performed (Figure 2) on the solid column version of the large-bar precast system, as well as a typical cast-in-place connection (for comparison). The precast system performed satisfactorily to a drift ratio of 5.5 percent before longitudinal bars buckled and fractured. This level of deformation is approximately three times the demand expected in a major earthquake and is comparable with the deformation achieved with a cast-in-place system. The large-bar, large-duct precast system appears to have sufficient strength and ductility capacity for all foreseeable seismic demands (Pang et al. 2008-1, Pang et al. 2008-2).

## **2.5 Proposed Work Plan**

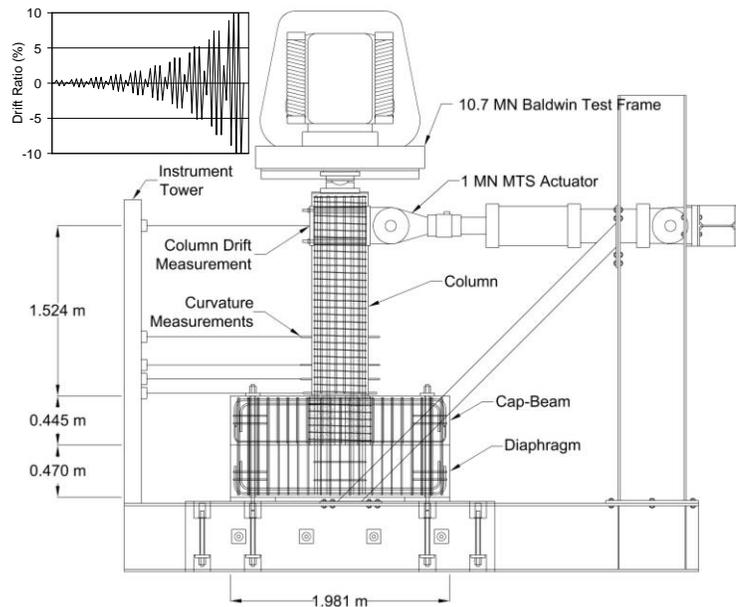
This section describes the remaining product development that will ensure that the product can be deployed in a wide range of applications. The remaining issues are addressed in four tasks: (1) proof testing of project-specific and alternative-design variations of the system, (2) development of project-specific and general design provisions and specifications, (3) development of design examples, and (4) the deployment of the basic system in the field.

### 2.5.1 Task 1. Proof Testing.

During Phase I, proof tests will be conducted to ensure that the proposed demonstration bridge will have acceptable seismic performance. (Phase I Project-Specific Tests).

Discussions with contractors and fabricators indicate that the optimal Accelerated Bridge Construction strategy depends on the characteristics of the specific project. For example, the most efficient solution may depend on the number of pieces being precast, the size of the columns, the layout space available on site, and the proximity of a good precast fabricator. In Phase II, proof tests will be conducted to ensure that product variations are available that can be implemented in a wide range of situations (Phase II Design Alternative Tests).

The proposed proof test specimens are shown in Figure 3. Specimens (a), (b) and (c) represent standard a solid cast-in-place column (to be used as a reference), a solid precast column, and a solid precast column with partially debonded bars (to reduce the strain concentrations). These have already been tested (as described in Section 2.4), and the data are available for comparison with the proposed test specimens (d)-(f). Specimens (d)-(f) will be tested as part of Task 1 of this project.



**Figure 2. Column-Beam Connection Test Set-up**

**Phase I.** Subtasks 1.1 to 1.4 are included in Phase I, because these need to be completed before the demonstration project is constructed. In Subtask 1.1, all of the test specimens will be designed in detail. This activity will be led by the University of Washington (UW) with input from the other team members. Subtask 1.2 consists of a constructability review to be conducted at the workshop to be convened by WSDOT. That workshop has several goals, but the immediate need in Task 1 is to obtain input from a broader spectrum of the construction industry, including a wider range of contractors, fabricators and WSDOT construction personnel. In Subtask 1.3, Tri-state Construction will fabricate the specimens at the UW, with such help from the UW lab staff as is necessary.

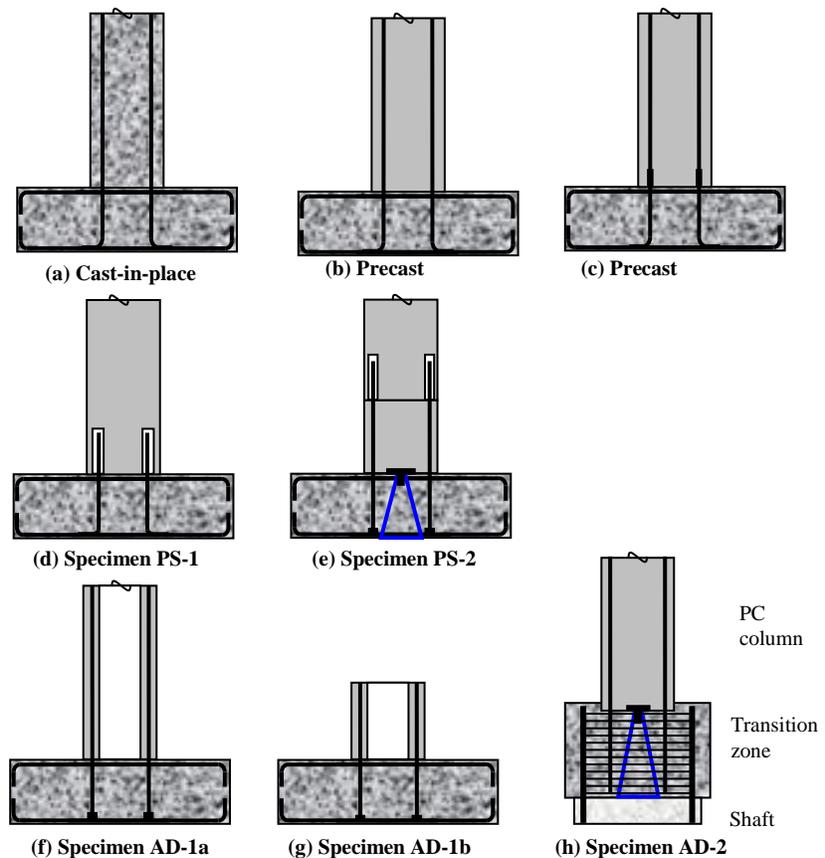
Subtask 1.4 consists of testing of the Project-Specific specimens, which are described below. These tests will consist of cyclic lateral load and constant vertical load applied to half-height columns, as illustrated in Figure 2. At a minimum, load and deflection of the column tip will be recorded, as well as strains in critical elements such as reinforcing bars. Two Project Specific tests (PS-1, PS-2) are proposed during Phase I.

**Test PS-1: Precast column grouted over bars in a cast-in place spread footing (Fig. 3d).** This configuration is intended to verify that a precast column can be grouted over starter bars projecting from a footing that is cast-in-place before the precast column is installed, and still provide seismic response that is equivalent to that of a conventional totally cast-in-place system. The characteristic that is open to question is the fact that all the (starter) bars would be connected

in the same plane, at the base of the column and therefore in the plastic hinge zone. Previous tests (Pang et al. 2008) on column-to-cap beam connections have shown that equivalent performance can be obtained if the bars project from the column into ducts in the cap beam. The same performance is presumed also to be available from a column connected to a footing in the same way. Here, however, the connection is reversed and the bars project from the footing and the ducts are in the column. There they are less well confined, because they are near the surface of the column rather than being deeply embedded in a large block of concrete (a cap beam or footing).

**Test PS-2: Spread footing cast around bars projecting from segmental precast column. (Fig. 3e).** This configuration is intended to test simultaneously two separate concepts, which could in fact be used independently: casting a precast column into a footing, and use of precast segmental column construction. A

central patch of concrete is first cast in the bottom of the footing. A steel pedestal with a hole in the top is centered and bolted down to the concrete. The footing reinforcement is then installed (either fabricated in place, or prefabricated and lifted in), the first column segment is lifted in and set on the pedestal. A short bar projecting from the column segment fits in the hole in the pedestal and automatically locates it in the correct position. The column segment is oriented (by swiveling about its vertical axis) as required and braced, and the footing is cast. The reinforcement projecting from the bottom of the column is embedded in the fresh footing



**Figure 3. Test Specimens**

concrete and leads to monolithic behavior of the two components. A second column segment is then placed on top of the first, and is secured using bars grouted into ducts. The test is intended to demonstrate that the bars-in-ducts splice provides sufficient strength to be used in low-demand regions of the column (typically the middle third of its height). If, as expected, the strength proves adequate, the yielding and damage will occur at the base of the column, which will permit evaluation of the footing connection detail.

**Deliverable:** At the end of Phase I, a preliminary test report will be delivered to BERGER/ABAM and WSDOT to provide the needed information to finalize the design specification for the demonstration project (Tasks 2.3 and 4.3).

**Phase II.** In Phase II, the Alternative Design tests will address the need to make the product more versatile. In Subtask 1.5, the Alternative Design proof tests will be conducted similarly to the tests conducted in Phase I. In Subtask 1.6, the test data will be reduced and interpreted in graphical form for easy comprehension and use in developing design Guidelines and Specifications (see Task 2).

**Test AD-1a and b: Hollow columns.** The weight of a column and the ease with which it can be transported, handled and erected are critical to constructability. In test PS-1, the performance of the segmental column will be evaluated in Phase I. The advantage of the segmental approach is that the size of the pieces can be optimized for any given crane capacity, regardless of column height. Segmentation also leads to a stockier, and therefore more stable, element that is easier to brace temporarily before all the connections are complete. Another approach is to make the columns hollow. The advantage of the hollow column is that it could be erected quickly in one piece with no intermediate joints.

Two hollow column specimens will be tested, one relatively slender and dominated by bending (Fig 3f), and the other relatively stocky and dominated by shear (Fig 3g). The potential failure modes to be studied are, respectively, internal spalling of the concrete and shear failure of the wall. If the needed level of confinement cannot be achieved and spalling occurs, the plastic hinge regions may be either made solid during precasting or filled with concrete after erection without serious impact on schedule. Too thick a wall increases the weight and detracts from constructability, while too thin a wall risks premature failure. The footing connection details will be selected after the results of the PS tests become available.

**Test AD-2.** Connection to Drilled Shaft (Fig 3h). Poor soil conditions necessitate large (e.g. 8 or 10 ft diameter) cast-in-place piles, called drilled shafts, rather than spread footings. The typical cast-in-place construction sequence is to cast the shaft up to about 10 ft below the ground surface, to place the column reinforcement cage in its precise location in plan in the “transition zone”, and then cast the transition zone, up to ground level. The projecting bars can then be used to construct the column. We propose to adapt that sequence to one similar to that of Specimen PS-2. A pedestal is set on the concrete at the bottom of the transition zone, and a precast column is set on it, braced and the transition zone concrete is cast around the projecting bars. This foundation connection could be used with a single-piece solid column, a hollow column (as AD-1) or a segmental column (as PS-2). The structural performance may differ from that of PS-2, because in the shaft the reinforcement consists of longitudinal bars surrounded by circular hoops, whereas the spread footing is typically reinforced with orthogonal mats of steel in its top and bottom.

**Deliverable:** The Final Report on the proof testing constitutes Subtask 1.7. This report will contain the test data relevant to evaluating the different approaches, and to development of general Design Guidelines and Specifications (Task 2.6).

### **2.5.2 Task 2. Development of Design Specifications**

One of the primary products of the proposed project is a set of proposed guidelines for designing precast bents in high seismic regions. The form of such guidelines will be modeled around eventual development into an AASHTO Guide Specification, to make them applicable across the country. In conjunction with this project, the WSDOT has identified a bridge replacement to be used as a demonstration project. The specification development of this task will first address the design and construction specification for that specific bridge in Phase I, then provisions will be developed for broader application in Phase II.

**Phase I.** Project Specific provisions will be developed in Phase I to support the design of the field demonstration project. The provisions will include both relevant design methodologies and special provisions for material and construction quality control. This work will be done in close coordination with WSDOT, who is the designer of the bridge. The approach is to capture the design methodologies established by the team for this bridge in a form that can be used as a straw man set of guidelines for internal review. It is important that such development begin early, because it takes significant amounts of time to develop consensus regarding new specification requirements and language.

**Phase II.** General provisions will be developed in the second phase using the project-specific straw-man language developed in Phase I. The product of Phase II is proposed AASTHO guide specification requirements that will be developed for seismic design in accordance with the displacement-based approach of the newly adopted Guide Specification for LRFD Seismic Bridge Design. These provisions will include more scope than that of the demonstration project alone. The proposed language will be developed by the project team and vetted through the WSDOT as independent reviewers, but also as knowledgeable owners. Workshops will be held with WSDOT to coordinate the design methods, constructability, and specific details of demonstration project, and during these workshops design specification format, scope and content will be established. By starting the specification language early in the project, it will be possible to write and gain consensus for a viable guide specification.

### **2.5.3 Task 3. Development of Design Examples**

The anticipated product from this work is a set of design configurations (e.g., example concrete outlines, configuration of internal reinforcement, suggested materials, example integration details with typical girder-bridge superstructures and foundations, and example design calculations unique to the precast concepts). A complete, detailed, design for a totally precast bridge bent should be conducted for both a single-column and a multi-column bent, and for spread footings and drilled shafts. The purpose would be to reveal (and correct) any weaknesses in the design as it is moved from concept to constructed facility.

A substructure type selection guide that compares the benefits, challenges, costs, and project delivery aspects of using precast substructures in lieu of conventional cast-in-place construction will be developed to help guide designers, contractors, and owners in selecting one construction method over the other.

During Phase I, selection of design examples will be made, and this will be accomplished by compiling a group of viable candidate bent types and then selecting specific features for which examples will be produced. This selection would be made as part of the project team workshop described in Section 2.5.2. In Phase II, the design examples will be fully developed. They will then be reviewed by WSDOT prior to finalizing them.

***Deliverables for both Tasks 2 and 3.*** These tasks will be accompanied by a set of design specifications that identify the current LRFD provisions that do not apply (because they are specific to cast-in-place construction) and then provide alternate substructure type selection guidance, design requirements, and design limits to be used for this system. The objective is to provide a complete system for designers to use immediately. To that end, example designs will also be provided to illustrate the application of the design methodology.

**2.5.4 Task 4 Deployment of Demonstration Structure.** The effectiveness of the product will be demonstrated at full-scale and under normal contracting conditions by constructing a bridge that carries SR12 over I-5 in Washington State. This two-span bridge will have a three-column bent located within the median of I-5. This high-profile bridge, located over the major N-S

interstate highway, provides an exceptional opportunity to demonstrate and evaluate the constructability and economy of the proposed connection system. Section 7 (Technical Information) provides further details of the bridge.

During Phase I, WSDOT will lead the initial design (Task 1.1), constructability review (Task 4.2) and begin the final design (Task 4.3) of the candidate bridge. These activities can proceed in parallel with the proof tests (PS-1 and PS-2), because we have confidence that there is little chance that this bottom detail will fail. If we are wrong, it is possible to use precast columns that have the proposed detail at the top of the column, while using a precast column with cast-in-place emulation at the bottom. This second detail has already been used in Washington State.

Year		2009												2010												2011	
Phase		Phase I												Phase II													
Calendar month		3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2		
Contract month no.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
No.	Task	Lead Org.																									
<b>Laboratory Testing</b>																											
1	1.1 Detailed Design of Test Specimens																										
	1.2 Workshop Review of Test Specimens																										
	1.3 Construct Specimens																										
	1.4 Project-Specific Tests																										
	1.5 Tests of Alternate Designs																										
	1.6 Data Reduction and Interpretation																										
	1.7 Write Final Report																										
<b>Guide Specifications</b>																											
2	2.1 Develop Trial Project-Specific Specifications																										
	2.2 Workshop Review of Project-Specific Specs																										
	2.3 Revised Project-Specific Provisions																										
	2.4 Develop Trial General Provisions																										
	2.5 Review of Provisions																										
	2.6 Write Final Specifications																										
<b>Design Examples</b>																											
3	3.1 Identify Candidate Configurations																										
	3.2 Workshop Review of Selected Design Examples																										
	3.3 Develop Draft Design Examples																										
	3.4 Review of Examples																										
	3.5 Develop Final Design Examples																										
<b>Field Demonstration Project</b>																											
4	4.1 Initial Design of Demonstration Project																										
	4.2 Constructability Review																										
	4.3 Final Design																										
	4.4 Publish Bid Documents																										
	4.5 Construct Project																										
	4.6 Evaluate and Document Lessons Learned																										
	4.7 Publish Summary Report																										
Final reporting																											

Figure 4. Proposed Schedule

The schedule for advertising (Task 4.4) and constructing (Task 4.5) the proposed bridge is ideal for this project. According to WSDOT, “The 100% submittal date for this project is January 25, 2010, and the projected advertisement date is April 5, 2010”. Thus, before FHWA approves Phase II, they can obtain confirmation from WSDOT that the demonstration project will indeed be advertised and constructed as soon as Phase II is approved.

**Deliverables:** Aside from the constructed bridge, the main deliverables for Task 4 will be a report (tasks 4.6 and 4.7) evaluating the lessons learned from implementing this product. The final report will be written by the BERGER/ABAM engineers, with the input of the full team.

**2.6 Project Management Plan and Schedule** The proposed tasks, schedule and lead organizations are shown in Figure 4. The project will be led by Dr. Lee Marsh of BERGER/ABAM Engineers Inc., who will also lead the tasks associated with development of the guide specifications and design examples. Professors John Stanton and Marc Eberhard at the University of Washington will be responsible for the testing conducted there. Mr. Greg Ritke will be in charge of construction planning and execution at Tri-State Construction. Mr. Steve

BERGER/ABAM Engineers, Federal Way, WA.

Seguirant will be responsible for precasting conducted at Concrete Technology Corporation, and Dr. Bijan Khaleghi of WSDOT will lead the review of the proposed specification provisions. In addition to these identified task leaders, the other team members will also contribute to each of the tasks and subtasks as reviewers and subject matter experts. The break between Phases I and II of the project has been established in conjunction with the first year end.

## **2.7 References**

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- Stanton, J.F., Eberhard, M.O. and Steuck, K. (2006), "Rapid Construction Details for Bridges in Seismic Zones," Proceedings, 22<sup>nd</sup> US-Japan Workshop on Bridges, Seattle, Oct.
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## **3 Commercialization Plan**

This innovation will be commercialized through application of the design provisions developed by this project, through continued application of the innovation by the participant organizations, and through support of Departments of Transportation that will benefit from the use of the innovation. The existence of a design specification will benefit those designers and/or contractors wishing to apply this technology to speed construction of bridges in high seismic regions, and this benefit will extend beyond the participants of this project. The work product of this project will be in the public domain, and it is not proprietary in any way.

Team members have made some use of such technology in the past, but the absence of proven design and construction methodologies has been an impediment to its acceptance by owners. The availability of specifications and design aids will allow this technology to be incorporated early in the design phases of candidate projects, such that owner sanction of the technique is built from the earliest stage of a project. BERGER/ABAM, Tri-State, and CTC all have strong histories of successful implementation of precast technology. This history and skill set, coupled with WSDOT's commitment to establish a working group on Accelerated Bridge Construction (ABC) technology, including the team members' proposed concepts, will help bring this important technology into broader practice. Additionally, the University of Washington's long-running efforts in this field will provide the WSDOT ABC team with the means to investigate and solve specific problems related to seismic performance. Thus, we expect that the proposed verification of this technology will permit a significant increase in the use of ABC in seismic regions, which will in turn reduce traffic delays and wasted fuel, and increase safety.

## **4 Organization, Personnel and Facilities**

The team includes all disciplines relevant to the goal of making totally precast bridge bent construction a reality: design, construction, precasting, structural testing, and DOT review and oversight. The team members have extensive experience in the development and construction unique precast solutions. Specifically, the proposal team consists of: (1) BERGER/ABAM

BERGER/ABAM Engineers, Federal Way, WA.

Engineers Inc. (Structural design engineers, Prime), (2) Tri-State Construction (General contractor), (3) Concrete Technology Corporation (Precast/prestressed concrete producer), (4) University of Washington (Structural testing) and (5) the Washington State Department of Transportation (Bridge and Structures Office)

Dr. Marsh at BERGER/ABAM (B/A) has 23 years of experience in the development of seismic design provisions for bridges, having worked recently to complete the AASHTO Guide Specifications for LRFD Seismic Bridge Design. He also has been involved with many of the firm's unique bridge and waterfront designs, including those with precast substructure elements. Additionally, B/A personnel (e.g. Jim Guarre and Chuck Spry) who have been involved with precast work will be included on the project team to fully leverage their experience.

Mr. Greg Ritke at Tri-State Construction originated the concept of using a site-precast concrete cap beam on cast-in-place columns in the SR 520 bridge in Redmond, Washington, and then implemented it in practice. He worked closely with WSDOT to achieve that change through a CRIP.

Mr. Steve Seguirant is the Director of Operations at Concrete Technology Corporation (CTC) and has been with the company for over 25 years. CTC fabricates most of the prestressed concrete girders used in the state of Washington, and, with WSDOT, Mr. Seguirant led the effort in the 1990s to develop prestressed concrete "supergirders" that can span over 200 ft.

Professors Eberhard and Stanton have conducted extensive research on precast concrete structures. Recently they developed and tested the large-bar connection for seismic cap-beam-to-column connections. Professor Stanton was also the lead designer on the NSF-sponsored PRESSS project in the 1990s that opened the way to the use of unbonded post-tensioned connections for seismic resistance in precast concrete buildings.

Dr Bijan Khaleghi is the Bridge Design Engineer and Concrete Specialist with WSDOT and is a member of AASHTO's T-10 Committee on Concrete Bridges, as well as other AASHTO, TRB, PCI, and ASBI technical committees related to concrete bridges. WSDOT sponsored, and Dr Khaleghi was actively involved in, the development of the large bar connection at the University of Washington. He was also an active participant in developing the supergirders.

The testing will be performed in the University of Washington Structural Research Laboratory. This facility has successfully conducted similar tests in the past.

## **5 Other Related Proposals**

The project team has no related proposals that are currently pending. Related proposals that have been submitted previously are for precast concrete connection review and evaluation (PRESSS Phase I, Stanton), design of a five-story precast concrete test building (PRESSS Phase III, Stanton). Ongoing work sponsored by the Washington State Department of Transportation concerns anchorage of large bars in grouted ducts (Eberhard and Stanton), seismic performance of precast column-to-cap beam connections (Stanton and Eberhard).

## **6 Patent Information and Proprietary Claims**

The proposed innovation has no pending or granted patents.